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Method for producing multi-layered preforms

The invention under consideration concerns a method according to the preamble of Claim 1 and the preforms produced by said method.

Particularly, the invention under consideration concerns a method which is suitable for producing three-layered preforms which show an increased recycled material content, allowing preforms to be produced with an improved barrier action against oxygen penetration.

Multi-layered preforms have been known for some time now and find usage in, amongst others, the beverage industry which produces plastic bottles from these preforms in situ which are then filled with the beverage concerned. Chiefly, such beverage bottles are manufactured from PET, although they may be produced from other thermoplastic materials such as PEN, polyamide, polycarbonate, etc.. Manufacturing plants of this type today produce 48 three-layered preforms per operating cycle by means of sequential injection moulding, amounting to an annual capacity of approx. 50 million units. In producing such preforms, new material is injected into the mould of the form tool in the first instance, followed by cleaned, prepared recycled material and, during a third stage in production, new material is injected again in order to rid the injection moulding nozzle of recycled material. Care is taken here to ensure that the tolerance on metering out individual injection quantities is kept as low as possible. Such accuracy in metering is a prerequisite for producing beverage bottles which show a high recycled material content as recycled material may not come into direct contact with the bottled beverage itself. Legal requirements stipulate this. When stretch blow moulding preforms into PET bottles, it must be ensured therefore that the inner layer of recycled material remains coated throughout by a layer of new material, a fact that places tough demands on

both the construction of injection moulding tools and on preform manufacturing plants. Unfortunately, the injection moulding machines we know today do not show the high levels of metering accuracy required for producing PET preforms which show a high recycled material content. As EP 0'655'306 confirms, it is for these reasons that PET bottles in use today generally show a recycled material content of, at best, only 25 %.

It is the aim of the beverage industry, however, to achieve a higher recycled material content on principle, for reasons both of cost and cost stability. Particularly, as regards ecological balance, the costs involved in producing returnable bottles fabricated from PET with 35 % recycled material are nearing those for non-returnable disposable bottles ("breakeven point"). An increased recycled material content would thereby increase the economic efficiency of re-useable PET bottles. Essentially, the level of economic efficiency depends on the wildly fluctuating price of new PET granules. If such granules are cheaper than recycled material, single-layer preforms fabricated from 100 % new material may be produced more cheaply, yet if the price rises above this breakeven point, three-layered preforms which show a recycled material content of 35 % and above are favourable. A higher recycled material content also results in improved price stability as the wild fluctuations seen in the price of new material will make a proportional difference only in those preforms using recycled PET. Cost implications for the manufacturer and the bottling firm are thus more favourable.

It is for this reason that is has already been suggested (Modern Plastics International, February 1997, page 29) that a co-extrusion blow moulding tool be used in the production of PET preforms and that product parts produced independently of one another be linked together. PET bottles which show a recycled material content of up to 80 % have been produced in this manner. A method of this type does, however, require additional tools and is proving to be complex and cost-intensive.

It is the aim of the beverage industry to produce formed bodies which meet with the law and show a high recycled material content without resorting to expensive technical measures.

The resulting technical problem is thus the way in which preforms can be produced with extremely thin layers of new material and without the use of expensive structures in order that the recycled material content of these preforms can be increased.

Particularly, the aim is to produce three-layered preforms which show at least one layer which is as thin as possible or a recycled material content of over 35 vol. %, particularly of 35 to 65 vol. %, by means of a simple procedure.

According to Claim 1, the solution to this problem lies in a surprisingly simple method for operating a multi-component injection moulding form tool and, particularly, in reversing the conventional arrangement for the supply of components A and B and operating the form tool in such a way that, in the first step in the cycle, the shut-off needle is brought into a position, wherein both the inner and the outer jet chambers are opened such that conveyance of component B through the outer jet chamber is stopped and only component A is injected into the mould cavity through the inner jet chamber.

In producing preforms which show a high recycled material content, the first component to be injected, component A (new material), is thus directed through the inner jet chamber to form a thin surface layer and the other component to be injected, component B (recycled material), is directed via the outer jet chamber to form a layer of filler. When injection moulding a three-layered preform of this type, in the first step in the cycle, the shut-off needle is brought into position I, wherein both the outer jet chamber containing component B and the inner jet chamber containing component A are opened. With the needle in this position, conveyance of component B is interrupted and component A is injected into the mould cavity.

In the second step in the cycle, the shut-off needle is brought into position II, wherein the inner jet chamber is closed and the outer jet chamber opened. With the needle in this position, conveyance of component A is interrupted and component B is injected into the mould cavity. The position of the shut-off needle remains unchanged for the next step in the cycle, the so-called holding phase, during which time shrinkage of component B due to cooling is replaced. Once the holding phase is over, the shut-off needle is brought into closing position III, wherein both the inner and outer jet chambers are closed.

Sub B'

~~It proves surprising that, during the next mould cycle, the first injection shot using component A is free from undesirable material B. This unexpected result can be explained by the reversal of the admission channels. Particularly, a small reduction in the viscosity of component A (new material) is achieved through the specific manner in which the individual components are conveyed, i.e. conveyance of component A through the slightly warmer inner jet chamber. In contrast to preforms produced using conventional methods of injection moulding, preforms with a thin surface layer (component A) can be created according to the inventive method and the relative proportion of filler material can be increased by component B material being loaded into the mould cavity during the holding pressure phase.~~

Moreover, the inventive method also allows preforms which show an extremely thin barrier layer (e.g. of nylon or similar) to be produced. Barrier layers of this type serve the purpose of minimising the degree of oxygen penetration within the formed bodies (bottles) and are comparatively expensive. In order to create a preform with a thin barrier layer according to the invention, the conventional arrangement of admission channels is again reversed and the barrier material to be injected to form the thin barrier layer is directed through the innermost jet chamber and the plastic forming the surface layer is fed through the outer jet chamber. When injection moulding a preform of this type, in the first step in the cycle, again the shut-off needle is brought into position I, wherein both the

outer and inner jet chambers are opened and the component directed through the outer jet chamber is injected into the mould cavity in the first step in the procedure, while at the same time conveyance of the barrier material directed through the inner jet chamber is interrupted. The shut-off needle remains in position I for the next step in the cycle and the barrier material conveyed through the inner jet chamber is loaded into the mould cavity at the same time as the filler material fed through the outer or central jet chamber. During this phase in injection moulding, both components (filler and barrier material) are thus conveyed at the same time, i.e. by means of tubes lying inside one another, thereby ensuring that the proportion of conveyed barrier material remains extremely low, e.g. making up 5 % of the overall injected material volume. The filler material and the material forming the surface layer may therefore be one and the same. Preferably, a relatively inexpensive recycled material is used for the filler material. This may be achieved in a well-known and simple manner by controlling the supply of molten plastics. In a third step in the cycle, conveyance of the barrier material is stopped once more and the filled mould cavity is further loaded with the amount of filler material required to compensate for shrinkage. By throwing the shut-off needle forward into position III, both jet chambers are closed and the mould cycle completed. The thin barrier layer lies in the central wall structure of the preform in all preforms produced in this manner. It is observed that preforms and formed bodies with layers arranged in such a manner provide the required barrier action against oxygen penetration within such containers.
Other embodiments of the inventive method are characterised by the features cited in the subclaims. Preforms created according to the inventive method of operation show a recycled material content of over 35 vol. % and, where necessary, a barrier layer material content of less than 5 vol. %.
The invention shall be described in further detail hereinafter with reference to an example. The illustrations given hereinafter show:

Figure 1: cross section through a hot runner nozzle and associated needle shut-off mechanism thereof;

Figure 2a to 2d: positions and control of the needle shut-off arrangement;

Figure 3: longitudinal section through a preform produced in the conventional manner;

Figure 4: longitudinal section through a preform produced according to the inventive method showing a high recycled material content;

Figure 5: longitudinal section through a preform produced according to the inventive method showing a barrier layer.

Figure 1 shows a section taken from the structure of a co-injection form tool used for two different components, A and B, complete with a hot runner nozzle 34 and a needle shut-off mechanism 36. The material melted in the extruders lands in the hot runner manifold block 15 via separate runners, is ramified therein and fed into the individual hot runner nozzles 34. Each of these hot runner nozzles 34 features a removable nozzle holder 33 and is constructed from several nozzle inserts lying inside one another between which one inner jet chamber 3 and at least one outer jet chamber 5 are created, through which the various synthetic components are fed up to the nozzle point. Heating elements keep both the hot runner manifold block 15 and the nozzle holder 33, and thereby the hot runner nozzle 34, at the required temperature. A pneumatic needle shut-off mechanism 36 controls a movable needle 37 located near the point of the hot runner nozzle 34 in order to release or block individual components A or B and/or C.

In the conventional method of operation, the shut-off needle 37 is brought into four different positions during the course of one mould cycle in order to, by way of example, fill a cavity with three layers. In the first position, the needle 37 is drawn backwards only as far as is required to load the cavity

with the first component, particularly original PET or raw material, via the outer jet chamber 5. In the second position, the needle 37 is drawn further backwards such that the second component, e.g. recycled PET, can also be pressed into the mould cavity via the inner jet chamber 3 before the needle 37 is nudged back into its intitial position for the holding phase and then nudged all the way forward in order to close the nozzle 34. The shut-off needle is therefore brought into four different positions during the course of one mould cycle, that is in order to a) open the outer jet chamber 5, b) open the inner jet chamber 3, c) close the inner jet chamber 3 and d) close the outer jet chamber 5.

As shown in Figure 1, the needle shut-off mechanism 36 is lodged in a groove on the top plate 13 which acts as a pneumatic cylinder and comprises the first plunger 38 which guides the needle 37, above which a second, flexible plunger 39 is fitted. A hermetical cylinder cover 40 seals off this groove so that it is compression-proof. Suitably arranged pressure pipes 41, 43 and 44 allow the individual plungers, and therefore the needle 37, to be brought into the desired position. Each of the individual pressure pipes presents the pressure required to move the needle. Usually, the outer pressure pipe 44 is pressurized to 20 bar, the central pressure pipe 43 to 10 bar and the inner pressure pipe 41 to 5 bar. The positioning of the individual plungers 38 and 39 shown in Figure 1 is achieved when the individual pressure pipes are pressurized as stipulated above. Should the needle 37 be drawn backwards into its initial position in order to release the first synthetic component in the conventional manner, the pressure in the central pressure pipe 43 simply needs to be raised or reduced accordingly. With that, the first plunger 38 moves up to the stop of the second plunger 39 due to the force of the pressure in the inner pressure pipe 41. To bring the needle 37 into the second position which opens up the supply of the second synthetic component via the inner jet chamber, the pressure in the outer pressure pipe 44 is raised or reduced analogously. This results in the two plungers 38, 39 moving

together up to the cylinder cover 40. To stop the supply of material once more, first the outer pressure pipe 44 is re-pressurized and with that the two plungers 38, 39 move together in the closing direction. Likewise, only when the central pressure pipe 43 is re-pressurized also can the outer jet chamber be interrupted by the movement of the first plunger 38. Compression-proof seals 51 and 52 are fitted on each individual plunger together with the seals 53 on the cylinder cover 40, ensuring that the pneumatic needle shut-off mechanism 36 works perfectly. An end seal 55 is also fitted in the nozzle holder 33 preventing pressure compensation occurring between the plunger arrangement 38, 39 and the nozzle arrangement 33, 34 and thus preventing pressurized steam penetrating along the needle 37 through the nozzle holder 33 from the individual, heated synthetic components, condensing on the walls of the plunger or on the nozzle needle and affecting or blocking the movability of the individual components in the needle shut-off mechanism 36. This is achieved in a well-known manner by the use of a gastight end seal 55 fabricated from temperature-resistant plastic.

According to the invention, to be able to produce multi-layered preforms which show an increased recycled material content or extremely thin layers using a multi-component injection moulding form tool of this type, the conventional arrangement for supplying components A and B is reversed and operated in such a way that component A is conveyed in the inner jet chamber 3 of the hot runner nozzle 34 together with only the material to be loaded to form a thin layer (new or barrier material) while component B is conveyed, together with the recycled material to be loaded, in the outer or central jet chamber 5 of the hot runner nozzle 34. Should a formed body be produced which shows a thin outer skin fabricated from new material as well as a thin barrier layer, new material is conveyed in the outermost of the three jet chambers, and the material forming the barrier layer in the innermost chamber, in such a manner that the material forming the barrier layer is squirted out of the central jet chamber at the same time as the filler material. When producing formed bodies which show a thin

barrier layer fabricated from one single base material, in the first step an initial portion of base material is injected into the mould cavity through the outermost of the two jet chambers and, in the second step, both base material and barrier material are injected into the mould cavity at the same time, i.e. by means of tubes lying inside one another. The needle 37 is thus brought into the positions as explained in further detail hereinafter with reference to Figures 2a to 2d.

Figures 2a to 2d show partial sections through the hot runner nozzle 34, complete with the associated needle shut-off mechanism 36 thereof. As shown in Figure 2a, the needle 37 is drawn backwards as far as is required to release the inner jet chamber in order to load the original component A conveyed via this inner jet chamber 3. By interrupting conveyance of component B and conveying component A, the required quantity of the original material A can be loaded into the mould cavity. As the original material A inside the hot runner nozzle 34 is shown to be less viscous than the filler material B in the outer jet chamber 5, it is sufficient to load only a small portion of the original material A into the mould cavity. This position of the needle, position I, can be achieved by reducing the pressure in pressure pipes 44 and 43 above the second plunger 39, or between the first plunger 38 and the second plunger 39, to 0 bar, for example, while building up the pressure in the pressure pipe 41 below the first plunger 38 to 6 bar, for example. Using this distribution of compressive forces, the two plungers find their highest possible position and the needle 37 thereby releases the inner jet chamber 3.

In the second step in the cycle as shown in Figure 2b, the needle 37 is brought into position II, wherein the inner jet chamber 3 is closed but the outer jet chamber 5 remains open. This is achieved by maintaining the pressure in the pressure pipe 41 at 6 bar, for example, while raising the pressure in the pressure pipe 44 above the second plunger 39 a little, to

10 bar, for example. In this position, component B (filler material) is conveyed into the mould cavity through the outer jet chamber 5. This material is more viscous than that out of the inner jet chamber 3 and it thus displaces the previously injected component A forming a thin film on the outer surfaces of the mould cavity, without penetrating the film. This difference in viscosity allows preforms to be produced with a thin outer skin. In the third step in the cycle, the mould cavity filled with the filler material B remains pressurized for a period, i.e. during the so-called holding phase, in order to compensate for any material volume lost through shrinkage.

Figure 2c shows the hot runner nozzle 34 and the needle shut-off mechanism 36 thereof in position III, wherein both the inner jet chamber 3 and the outer jet chamber 5 are closed. This is achieved by reducing the pressure in the pressure pipe 41 below the first plunger 38 to 0 bar, for example, and raising the pressure in the pressure pipe 43 between the two plungers to 6 bar, for example, at the same time while keeping the pressure in the pressure pipe 44 above the second plunger 39 at 10 bar, for example.

Conventionally, and without reversed delivery channels for components A and B, the mould cycle starts with the needle in the position shown in Figure 2b in order to load component A (new material) into the mould cavity. The shut-off needle 37 is subsequently brought into position I to fill the mould cavity with component B (filler material). As shown in Figure 2d, the needle is brought back into position II for the holding phase in order to replace material shrunk due to cooling with component A and to ensure that component B (recycled material) does not land in the cavity first during the next mould cycle. To complete the cycle the needle is brought into position III, as shown in Figure 2c.

It is thus clear that in the method of operation under consideration, the mould cycle is completed when filler material shrinkage is replaced with the same component, while conventionally the volume of material shrinkage is replaced with whichever component is to be injected first during the next mould cycle. In the method under consideration, component B (recycled material) may be loaded repeatedly into the mould cavity but surprisingly it is observed that it is only component A, in fact, which lands in the mould cavity due to the lower viscosity of component A fed through the inner jet chamber and because conveyance of component B is interrupted at the beginning of the next mould cycle; it is in this manner that the tough requirements demanded by the beverage industry can be met as regards blow-moulded bodies which show an intact outer or inner skin.

The longitudinal sections shown in Figures 3 and 4 make clear the distinction between the inventive method and the conventional method. Figure 3 shows a longitudinal section through a preform produced in the conventional manner with a threaded section 61 and a barrel section 62, the sprue 63 thereof lying in the bottom section 64. From this longitudinal section it is also evident that neither the inner skin 65 nor the outer skin 66 (except at sprue) is penetrated at any point by the filler material B. Particularly critical points here are the deformations in the threaded section 61 of the preform. In addition, this illustration makes clear the manner in which the volume of filler material shrunk during the holding phase is replaced with new material A. Particularly, the percentage of recycled material used is substantially reduced by this new material being additionally loaded into the bottom section 64.

In contrast, Figure 4 shows a longitudinal section through a preform produced according to the inventive method. Essentially, this differs in the structure of the bottom section 64 which shows just three layers, namely an inner skin,

filler material and an outer skin. Moreover, a fundamental distinction is shown in the thickness of the individual layers. Conventional preforms weighing 48.0 g with an overall wall thickness of 4.37 mm which are suitable for 1.5 litre bottles have an outer skin with a thickness of 1.3 to 1.5 mm. This results in a volume percent of 25 to 33 vol. % as regards the innerlying filler material. In the case of preforms also weighing 48.0 g produced according to the inventive method as shown in Figure 4, the outer material 65, 66 shows a thickness of 1.2 to 0.6 mm, therefore allowing the percentage of filler material to be increased to 37 to 63 vol. % through the application of this particular method of manufacture.

By reversing the admission channels, preforms can also be produced with a barrier layer (e.g. of nylon, EVOH or similar) which shows an improved barrier action against oxygen. This shall be explained in further detail with reference to Figures 2a to 2c. According to the inventive method, during the production of preforms with a barrier layer, the needle 37 is brought into position II (Figure 2b) in the first step in the cycle in order to fill the cavity with material used for the surface layer. In the second step in the cycle, the shut-off needle 37 is brought into position I (Figure 2a) and the barrier material (e.g. nylon) conveyed through the inner jet chamber 3 is injected into the mould cavity together with the component fed through the outer jet chamber 5. Barrier material therefore ends up lying in the inner wall structure of the preform allowing the formed body to be provided with an extremely thin barrier layer of approx. 5 vol. % or less. 17

In a preferred embodiment, the barrier material is directed through the innermost jet chamber and the method allows the needle 37 to be brought into position I in the first step in the cycle, wherein both the inner and the outer jet chambers are opened but only the material directed through the outer jet chamber 5 is conveyed into the mould cavity while conveyance of

the material directed through the inner jet chamber 3 is stopped. The needle 37 remains in position I for the second step in the cycle and material is conveyed through the outer jet chamber 5 at the same time as the barrier layer material conveyed through the inner jet chamber 3, resulting in a barrier material content of approx. 5 % or less of the overall injected material. To compensate for material shrinkage during the holding phase, the shut-off needle remains in position I and conveyance of the barrier material conveyed through the inner jet chamber 3 is suspended. Following successful loading, the needle is brought into position III (Figure 2c) in order to close the inner and outer jet chambers. Preforms produced in this manner show a thin barrier layer which lies in the central wall structure of the preform.

The advantages shown by the inventive method and by the preforms created according to this method are immediately obvious to the specialist. Particularly, the conventional method requires four needle positions in succession for each mould cycle whereas the inventive method requires only two or three needle positions. This simplifies control of the needle shut-off mechanism. Moreover, according to the invention, shrinkage in component B is replaced with the same material, increasing the percentage of this component (recycled material) or lowering the percentage of the component fed through the innermost jet chamber. The acquisition of new and expensive machines or tools is not required to put the inventive method into practice.

Further developments, particularly those affecting the viscosity of individual components and those used in controlling the mould cycle, lie within the normal capacities of a person skilled in the art. It is understood that all plastics used in injection moulding technology, especially nylon, and not only PET material, may be processed using this method.